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**Testing methods for performance of
pump using model pump**

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry, through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by The Japan Society of Industrial Machinery Manufacturers (JSIM)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently **JIS B 8327:2002** is replaced with this Standard.

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Testing methods for performance of pump using model pump

Editor's note: This English-translated edition includes some discrepancies from the original Japanese edition, which involve correction of errors or modifications made in the process of editing.

1 Scope

This Japanese Industrial Standard specifies the methods for testing the performance (including cavitation performance, etc.) of pumps served for practical use (hereafter referred to as prototype pumps) in their delivery inspection, by using a model pump which corresponds to the prototype pumps.

The matters related to pump tests not specified in this Standard are given in **JIS B 8301** and **JIS B 8302**.

This Standard is applicable to large size centrifugal pumps, mixed flow pumps and axial flow pumps, but not applicable to pump turbines.

NOTE : The model pump test performed in accordance with this Standard can substitute the performance test on prototype pumps in their delivery inspection. This Standard does not interfere with temporary assembly inspections, etc. of the prototype pumps.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS B 0131 *Glossary of terms for turbopumps*

JIS B 0601 *Geometrical Product Specifications (GPS)—Surface texture: Profile method—Terms, definitions and surface texture parameters*

JIS B 7516 *Metal rules*

JIS B 7547 *Procedures of characterization and calibration for digital pressure gauges*

JIS B 7552 *Procedures for calibration and testing for liquid flowmeter*

JIS B 7554 *Electromagnetic flowmeters*

JIS B 8301 *Rotodynamic pumps—Hydraulic performance acceptance tests—Grades 1 and 2*

JIS B 8302 *Measurement methods of pump discharge*

JIS Z 8401 *Guide to the rounding of numbers*

JIS Z 8762-1 *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full—Part 1: General principles and requirements*

JIS Z 8762-2 *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full—Part 2: Orifice plates*

JIS Z 8762-3 *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full—Part 3: Nozzles and Venturi nozzles*

JIS Z 8762-4 *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full—Part 4: Venturi tubes*

JIS Z 8765 *Method of flow measurement by turbine meters*

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in **JIS B 0131**, and the following apply.

3.1 General terms and definitions

3.1.1 performance test

test to examine the performance of a pump in the state free from influence of cavitation

3.1.2 cavitation test

test to examine change in pump total head caused by cavitation, using a model pump which has been set to operating conditions corresponding to the service conditions of the prototype pump

3.1.3 NPSH test

test performed by lowering the NPSH and thereby simulating cavitation of the model pump to determine the NPSH at which the pump total head of the model pump drops by 3 % due to cavitation

NOTE : NPSH is an abbreviation for Net Positive Suction Head.

3.1.4 four quadrant characteristics test

test to examine characteristics of the model pump in the pump region, pump brake region, turbine region, turbine brake region and reverse pump region

NOTE : The purpose of this test is to obtain the characteristics necessary for carrying out calculation analyses of transitional phenomena of a pump.

3.1.5 specified speed of rotation

speed of rotation selected to indicate the performance of the model pump corresponding to the prototype pump specification agreed between the purchaser and manufacturer

3.1.6 test speed of rotation

practically measured value of the speed of rotation of the model pump obtained in the model pump performance test and cavitation test

3.1.7 specified capacity

flow rate at the specified speed of rotation of the model pump corresponding to prototype pump specification agreed between the purchaser and manufacturer

3.1.8 specified pump total head

pump total head at the specified speed of rotation and specified capacity of the model pump corresponding to the prototype pump specification agreed between the purchaser and manufacturer

3.2 Terms and definitions regarding performance

3.2.1 reference plane

horizontal plane taken as a reference for potential head, used in calculation of discharge head, suction head, etc.

3.2.2 NPSH datum plane

horizontal plane through the centre of the circle described by the external points of the entrance edges of the impeller

NOTE : For multistage pumps, this applies to the first stage impeller, and for vertical shaft double suction pumps, to the topmost vane (see Figure 1).

3.2.3 specific energy, y

energy per unit mass of a liquid

NOTE : The unit used is Joule per kilogram (J/kg).

3.2.4 head, H

specific energy divided by acceleration of gravity (g)

NOTE : The unit used is metre (m).

For g , it is preferable that a local value is used. In many cases, however, the use of 9.80 m/s^2 will not lead to significant error. Local value shall be obtained according to the following.

$$g = 9.7803 \times (1 + 0.0053 \sin^2 \phi) - 3 \times 10^{-6} \cdot Z$$

where, ϕ : latitude ($^\circ$)

Z : altitude (m)

3.2.5 pump total head, H

difference in the total head between the pump discharge opening and the suction opening

NOTE : The unit used is metre (m).

3.2.6 flow rate, Q

volume of liquid, per time, discharged by a pump

NOTE : The unit used is cubic metre per second (m^3/s).

3.2.7 speed of rotation, n

number of rotations, per time, of a rotating body

NOTE : The unit used is per second (s^{-1}).

3.2.8 pump power input, P

power which is transmitted to a pump shaft by a driver

NOTE : The unit used is kilowatt (kW).

3.2.9 pump efficiency, η

ratio of pump power output to pump power input

NOTE : The unit used is percent (%).

3.2.10 NPSH, $NPSH$

difference between the total pressure (absolute pressure) of the liquid at the suction opening of the pump and the saturated vapour pressure (absolute pressure) at the temperature of that liquid, expressed on the NPSH datum plane of the pump

It is used for consideration of cavitation and calculated by the following:

$$NPSH = \frac{(p_t - p_v)}{\rho \cdot g}$$

where, $NPSH$: net positive suction head (m)

p_t : suction total pressure expressed by absolute value on the NPSH datum plane (Pa)

p_v : saturated vapour pressure at the water temperature at the time of measuring (Pa)

ρ : density (kg/m^3)

g : acceleration of gravity (see 3.2.4) (m/s^2)

3.2.11 available NPSH (NPSHA), $NPSHA$

NPSH specified by the pump installation requirements

NOTE : The unit used is metre (m).

3.2.12 NPSH3, $NPSH3$

NPSH at which the pump total head of the first stage drops by 3 %

NOTE : The unit used is metre (m).

3.2.13 Reynolds number, Re

ratio of inertia force to viscous force

The Reynolds numbers used for conversion of prototype pump and model pump hydraulic efficiencies shall be calculated as follows.

$$Re_{hp} = \frac{u_{1p} \cdot D_{1p}}{\nu_p}$$

$$Re_{hM} = \frac{u_{1M} \cdot D_{1M}}{v_M}$$

- where, Re_{hP} : Reynolds number of prototype pump (—)
 Re_{hM} : Reynolds number of model pump (—)
 D_{1P} : impeller inlet tip diameter of prototype pump (m)
 D_{1M} : impeller inlet tip diameter of model pump (m)
 n_P : speed of rotation of prototype pump (s^{-1})
 n_M : speed of rotation of model pump (s^{-1})
 v_P : kinematic viscosity of the liquid in prototype pump (m^2/s)
 v_M : kinematic viscosity of the liquid in model pump (m^2/s)
 u_{1P} : peripheral velocity at the impeller inlet tip diameter of prototype pump (m/s)
 $u_{1P} = \pi D_{1P} \cdot n_P$
 u_{1M} : peripheral velocity at the impeller inlet tip diameter of model pump (m/s)
 $u_{1M} = \pi D_{1M} \cdot n_M$

The Reynolds numbers used for conversion of prototype pump and model pump mechanical efficiencies shall be calculated as follows.

$$Re_{mP} = \frac{u_{2mP} \cdot (D_{2mP} / 2)}{v_P}$$

$$Re_{mM} = \frac{u_{2mM} \cdot (D_{2mM} / 2)}{v_M}$$

- where, Re_{mP} : Reynolds number of prototype pump (—)
 Re_{mM} : Reynolds number of model pump (—)
 D_{2mP} : impeller outlet mean diameter of prototype pump (m)
 $D_{2mP} = \sqrt{\frac{D_{2sP}^2 + D_{2bP}^2}{2}}$
 D_{2sP} : impeller outlet diameter on the shroud side of prototype pump (m)
 D_{2bP} : impeller outlet diameter on the boss side of prototype pump (m)
 D_{2mM} : impeller outlet mean diameter of model pump (m)

$$D_{2mM} = \sqrt{\frac{D_{2sM}^2 + D_{2bM}^2}{2}}$$

D_{2sM} : impeller outlet diameter on the shroud side of model pump (m)

D_{2bM} : impeller outlet diameter on the boss side of model pump (m)

u_{2mP} : peripheral velocity at the impeller outlet mean diameter of prototype pump (m/s)

$$u_{2mP} = \pi \cdot n_P \cdot D_{2mP}$$

u_{2mM} : peripheral velocity at the impeller outlet mean diameter of model pump (m/s)

$$u_{2mM} = \pi \cdot n_M \cdot D_{2mM}$$

n_P : speed of rotation of prototype pump (s^{-1})

n_M : speed of rotation of model pump (s^{-1})

NOTE : The unit is dimensionless.

3.2.14 peripheral velocity, u

velocity in the tangential direction of a rotor

NOTE : The unit used is metre per second (m/s).

3.2.15 kinematic viscosity, ν

value obtained by dividing viscosity by density as follows:

$$\nu = \frac{\mu}{\rho}$$

where, μ : viscosity ($\text{Pa} \cdot \text{s}$)

ρ : density (kg/m^3)

NOTE : The unit used is square metre per second (m^2/s).

3.2.16 loss of head, H_{j1} (suction), H_{j2} (discharge)

difference in the total head between the measurement point and the pump suction cross-section or the pump discharge cross-section

NOTE : The unit used is metre (m).

3.2.17 pipe friction loss coefficient, λ

coefficient used for determining the loss of head due to friction in a pipe

NOTE : The unit is dimensionless.

3.2.18 equivalent diameter, D_e

diameter four times the channel cross-sectional area divided by the wetted perimeter of the cross-section

It is also referred to as hydraulic diameter.

NOTE : The unit used is metre (m).

3.2.19 pump power output, P_w

effective energy, per time, which a pump gives the liquid

It is also referred to as hydraulic power.

NOTE : The unit used is kilowatt (kW).

3.2.20 hydraulic efficiency, η_h , and hydraulic efficiency ratio, F_h

- a) **hydraulic efficiency** proportion of the pump total head to the theoretical pump head (pump impeller head without any hydraulic loss)

NOTE : The unit used is percent (%).

- b) **hydraulic efficiency ratio** ratio between the hydraulic efficiency of an prototype pump and that of a model pump at the corresponding operating point

NOTE : The unit is dimensionless.

3.2.21 mechanical efficiency, η_m , and mechanical efficiency ratio, F_m

- a) **mechanical efficiency** proportion of the power that an impeller transmits to a liquid to the pump power input.

The losses at the bearings and seals are excluded and only the disc friction loss of power is considered.

NOTE : The unit used is percent (%).

- b) **mechanical efficiency ratio** ratio between the mechanical efficiency of the prototype pump and that of a model pump at the corresponding operating point

NOTE : The unit is dimensionless.

3.2.22 volumetric efficiency, η_v , and volumetric efficiency ratio, F_v

- a) **volumetric efficiency** proportion of the pump flow rate to the flow rate through an impeller

NOTE : The unit used is percent (%).

- b) **volumetric efficiency ratio** ratio between the volumetric efficiency of an prototype pump and that of a model pump at the corresponding operating point

NOTE : The unit is dimensionless.

3.2.23 hydraulically smooth surface roughness, e_{adm}

surface roughness in which the frictional resistance is equal to that working on a geometrically perfectly smooth surface, where the wall surface roughness is within the viscous sub-layer of a boundary layer

NOTE : The unit is micrometre (μm).

3.2.24 scale effect coefficient, V

proportion of the loss due to the scale effect to the combination of scalable and non-scalable losses.

The loss due to the scale effect is equal to a loss due to friction of wall surface of flow passages.

NOTE : The unit is dimensionless.

3.2.25 cavitation

formation of high-speed two-phase flow composed of liquid phase and its vapour, obtained due to phase transition from liquid to vapour resulting from reduction in pressure caused by high-speed flow

3.2.26 cavitation coefficient, σ

value obtained by dividing the NPSH by the velocity head of the peripheral velocity at the impeller inlet, which is calculated as follows:

NOTE : The unit is dimensionless.

$$\sigma = \frac{g \cdot NPSH}{u_1^2 / 2}$$

where, σ : cavitation coefficient (—)

$NPSH$: (see 3.2.10)

u_1 : peripheral velocity at the impeller inlet tip diameter (m/s)

3.2.27 specific speed, n_s

value obtained using the following formula by taking a flow rate per impeller eye and pump total head per stage as Q' and H' , respectively, and further taking the units of n , Q' and H' as min^{-1} , m^3/min and m , respectively:

$$n_s = \frac{n \cdot \sqrt{Q'}}{(H')^{3/4}}$$

This is a value derived from the hydrodynamic similarity rule, given for the performance at the maximum efficiency point and is almost constant regardless of the sizes and the speeds of rotation of pumps of similar shapes.

3.2.28 type number, K

value obtained using the following formula by taking a flow rate per impeller eye and pump total head per stage as Q' and H' , respectively:

$$K = \frac{2\pi n \sqrt{Q'}}{(gH')^{3/4}} = \frac{\omega \sqrt{Q'}}{y'^{3/4}}$$

where, K : type number (—)

n : speed of rotation (s^{-1})

Q' : flow rate per impeller eye (m^3/s)

H' : pump total head per stage (m)

ω : angular velocity (rad/s)

y' : specific energy per stage (J/kg)

Like specific speed, this is a dimensionless index indicating an approximate configuration of an impeller of rotodynamic pump and is obtained at the maximum efficiency point.

3.2.29 meridian direction

direction of a meridian plane (plane including the axis of rotation)

3.3 Terms and definitions regarding measurement uncertainty

3.3.1 uncertainty, u

quantity for evaluating dispersion of values attributed to a measured quantity which can inevitably occur in any measurement

3.3.2 standard uncertainty, s

standard deviation, calculated by the following formula:

$$s = \sqrt{\frac{1}{N-1} \sum_{j=1}^N (x_j - \bar{x})^2}$$

where, s : standard deviation (dimension of observed values)
 N : number of groups of measured values (—)
 x_j : measured value (dimension of observed values)
 $\bar{x}$: arithmetic mean of measured values (dimension of observed values)

3.3.3 Type A uncertainty, u_r

uncertainty in evaluation of measured values by means of a statistical analysis method

3.3.4 Type B uncertainty, u_s

uncertainty in evaluation of measured values by means of other analysis method than statistical analysis method

3.3.5 combined uncertainty, u_c

uncertainty obtained by combining Type A and Type B uncertainties, each expressed as standard deviations, according to the following formula:

$$u_c = \sqrt{u_r^2 + u_s^2}$$

where, u_c : combined uncertainty
 u_r : Type A uncertainty
 u_s : Type B uncertainty

3.3.6 sensitivity coefficient, S_f

quantity of a calculated value, expressed as a combination of measured quantities, which is partially differentiated by each quantity

3.3.7 expanded uncertainty, U_c

uncertainty which has been expanded corresponding to an interval (confidence interval) expected to contain a major part of the distribution of values which can be reasonably connected with measured values with respect to the measurement results, which is defined as follows:

$$U_c = k \cdot u_c = k \cdot \sqrt{u_r^2 + u_s^2}$$

where, U_c : expanded uncertainty
 k : coverage factor (—)

3.3.8 confidence level

interval expected to contain a major part of the distribution of values which can be reasonably connected with measured values with respect to the measurement results, which is normally 95 %

3.3.9 coverage factor, k

factor by which a combined uncertainty is multiplied in order to calculate an expanded uncertainty

NOTE 1 Normally, $k=2$.

NOTE 2 The unit is dimensionless.

3.3.10 budget table

table which collectively tabulates contributing factors of individual uncertainties and their values in order to present the overall uncertainty

3.3.11 Student's t distribution

one of continuous probability distributions, which is calculated in accordance with the formula below

This probability distribution can be brought close to a normal distribution (Gaussian distribution) by increasing the number of samples, N .

$$t = \frac{\bar{x}_N - \mu}{(s_N / \sqrt{N})}$$

where, t : Student's t distribution (—)
 $\bar{x}_N$: arithmetic mean of observed values (dimension of observed values)
 μ : population mean (dimension of observed values)
 N : number of groups of measured values (—)
 s_N : unbiased standard deviation (dimension of observed values)

3.3.12 international measurement standard

measurement standard based on a scheme [Global Mutual Recognition Arrangement (MRA) by International Committee of Weights and Measures (CIPM)], in which each member nation trusts their partner nations' measurement traceability systems, each

having their own national measurement standard body at the top of its hierarchy, and recognizes the calibration data obtained by that standard as equivalent to their own and accept their calibration certificates without any further assessment

4 Symbols and subscripts

For the purpose of this Standard, the symbols given in Table 1, and subscripts and their definitions given in Table 2 apply.

Table 1 Main symbols and their units

Symbol	Quantity	Unit
A	area	m^2
B	impeller outlet width	m
b	annular radial clearance	m
C	friction torque coefficient	Dimensionless
C	leakage loss coefficient	Dimensionless
C, C_d	clearance between the gauge and the impeller cross-sectional shape as shown in Figures 3 to 6	m
D	diameter	m
d	annular clearance diameter	m
e	surface roughness	μm
e	uncertainty	Unit of each physical quantity to be measured
F	ratio of efficiency	Dimensionless
F	axial thrust	N
f	frequency	s^{-1}
g	acceleration of gravity	m/s^2
H	pump total head or total head (used with a subscript specifying the position)	m
H	height	m
K	type number	Dimensionless
k	coverage factor	Dimensionless
L, l	length or distance	m
N	number	Number of groups of measured values
n	speed of rotation	s^{-1}
P	pump power input	kW
p	pressure	Pa
P	pitch	m
Q	flow rate	m^3/s
S	clearance	m
S	sensitivity coefficient	%/(Unit of each physical quantity to be measured)
s	standard deviation	Unit of each physical quantity to be measured

Table 1 (concluded)

Symbol	Quantity	Unit
T	torque	Nm
t	time	s
t	tolerance	Dimensionless
U	expanded uncertainty, relative expanded uncertainty	Unit of each physical quantity to be measured or %
u	mean velocity (used for a flow in a pipe), peripheral velocity (used for a flow in a pump)	m/s
u	uncertainty, relative uncertainty	Unit of each physical quantity to be measured or %
V	scale effect coefficient	Dimensionless
v	local velocity	m/s
W	width	m
X, x	measured value	Unit of each physical quantity to be measured
y	specific energy	J/kg
Z	altitude	m
z	height from a reference plane	m
α	influence factor of pump total head in hydraulic efficiency ratio between prototype and model pumps	Dimensionless
β	influence factor of pump power input in hydraulic efficiency ratio between prototype and model pumps	Dimensionless
Δ	difference or fluctuation, in combination with a symbol to follow	Unit of each physical quantity to be measured
ε	range of fluctuation	Unit of each physical quantity to be measured
ζ	loss coefficient	Dimensionless
η	efficiency	%
θ	direction of radial thrust, vane setting angle	rad or degree
Λ	friction torque coefficient ratio	Dimensionless
λ	pipe friction loss coefficient	Dimensionless
ν	kinematic viscosity	m ² /s
ρ	density	kg/m ³
σ	cavitation coefficient	Dimensionless
ϕ	latitude	degree
ω	angular velocity	rad/s

Table 2 Subscripts and their meanings

Subscript [word(s) of origin]	Meaning
1	suction or inlet
2	discharge or outlet
a (axial)	axial direction
adm (admissible)	maximum admissible value
B (wetted)	wetted perimeter
b (boss)	boss (or hub)
c (circumferential)	circumferential direction
c (combined)	combined uncertainty
d (diffuser)	diffuser or volute
ED (specific energy and diameter)	dimensionless coefficient of four quadrant characteristics
e (expanded or equivalent)	expanded uncertainty or equivalent diameter
f (friction)	friction loss of head
G (guarantee)	guarantee point
g (gap)	clearance
<i>H</i> (head)	pump total head
h (hydraulic)	hydraulic efficiency
e (impeller)	impeller
<i>i, j</i> (integer number)	number of order of groups of measured values or stages (1, 2, 3 ...)
<i>L</i> (loss)	loss of power (mechanical efficiency)
M (model)	model pump
m (mechanical)	mechanical efficiency
max (maximum)	maximum
mean (mean)	mean
min (minimum)	minimum
<i>N</i> (number)	number of groups of measured values
opt (optimum)	maximum efficiency point
P (prototype)	prototype pump
<i>Q</i> (quantity)	volume rate of flow
r (random)	Type A uncertainty (random component of uncertainty)
r (radial)	radial direction
s (standard)	standard of scale effect coefficient
s (suction or shroud)	suction pipe or shroud
s (systematic)	Type B uncertainty (systematic uncertainty)
s (standard)	standard deviation
sp (specified)	specified value
<i>t</i> (total)	total pressure
V (volute)	volute casing
<i>v</i> (vapour)	vapour pressure
v (volumetric)	volumetric efficiency

Table 2 (concluded)

Subscript [word(s) of origin]	Meaning
w (water)	hydraulic power
x (x coordinate axis)	abscissa
y (y coordinate axis)	ordinate

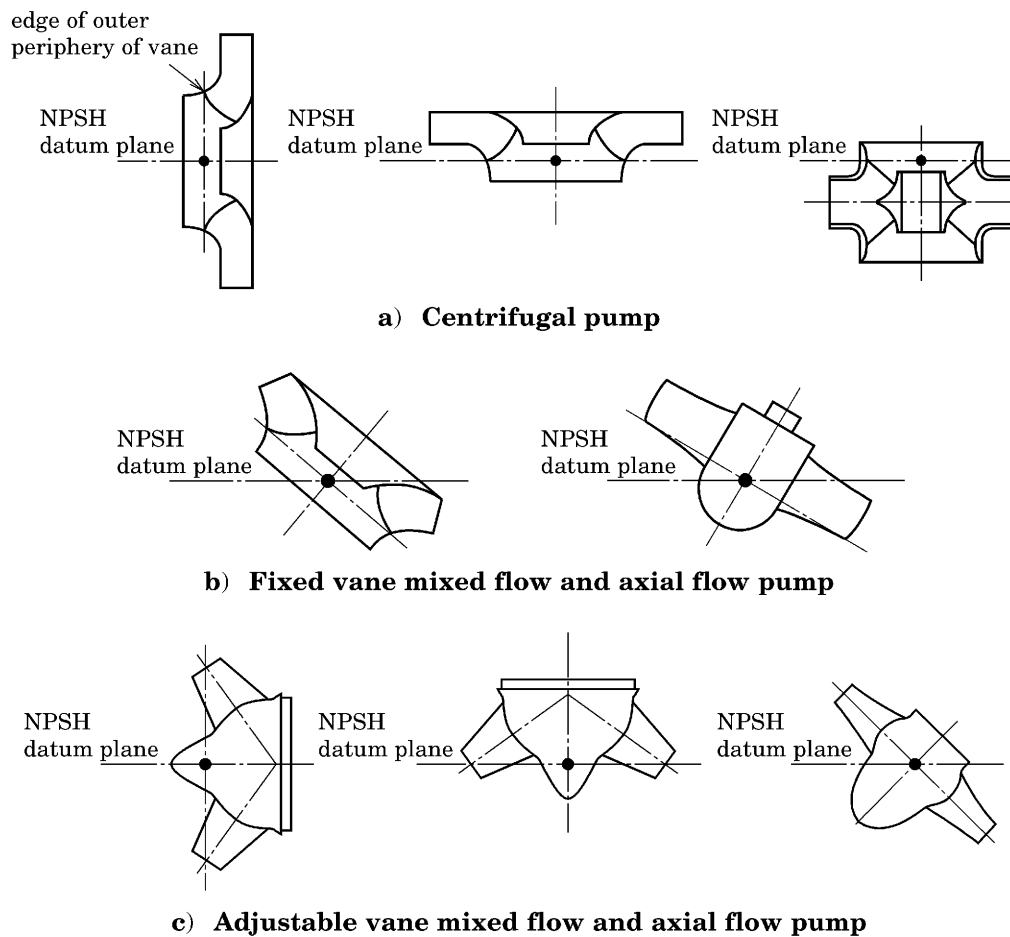


Figure 1 NPSH datum plane

5 Types of test and measuring items

The tests on pump shall be as given in Table 3. The tests in 2) and 3) shall be only performed if agreed between the purchaser and manufacturer.

As a rule, all of the following tests shall be carried out using the identical model pump.

Table 3 Tests on pumps

Type of test	Measuring items
1) Performance test	Pump total head, flow rate, speed of rotation, pump shaft torque or pump power input, pump efficiency and NPSH
2) Cavitation test or NPSH test	
3) Additional tests	See Annex A.

6 Model pump

6.1 Extent of model pump

The model pump shall include the part between the suction opening and the discharge opening (see Figure 2). If the suction channel/discharge channel is structurally part of the pump and therefore the suction opening and discharge opening cannot be identified, sections where the flow velocity distribution is found to be uniform shall be taken as the inlet and outlet of the model pump.

Alternatively, the range can be agreed between the purchaser and manufacturer.

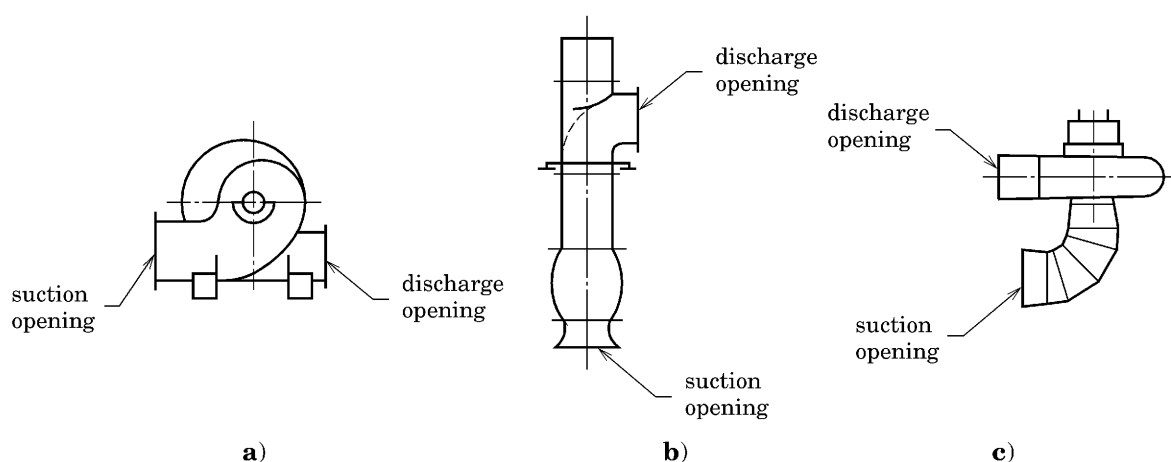


Figure 2 Extent of model pump

6.2 Dimensional ranges of model pump

6.2.1 Reynolds number

The Reynolds number Re_{HM} of the model pump, centrifugal or mixed and axial flow, shall be 2×10^6 minimum.

6.2.2 Impeller dimensions

The maximum outer diameter of the impeller of the model pump shall be 300 mm or larger. For impellers having adjustable vanes, the maximum outer diameter shall be measured at the design vane setting angle. Where manufacturing accuracy can be ensured, this dimension may be otherwise agreed between the purchaser and manufacturer.

6.2.3 Pump total head

The pump total head of the model pump shall be decided so that the performance measurement accuracies can be ensured while satisfying the requirements in 6.2.1 and 6.2.2.

6.3 Construction of model pump

6.3.1 Range of similarity

All the parts forming the model pump channels shall be geometrically similar to the corresponding parts of the prototype pump. When this is difficult, the range of similarity may be agreed between the purchaser and manufacturer.

6.3.2 Permissible dimensional deviation

The main dimensions of the model pump, as shown in Figures 3 to 7, shall be measured by referring to the model pump drawings. For these dimensions, the permissible deviations given in Table 4 or 6 shall apply.

When the measured model pump dimensions are within the deviations in Table 4 or 6, the model pump shall be regarded as being similar to the prototype pump.

A three-dimensional measuring device may be used in addition to vane gauges to measure the vane shape at the discrete points as shown in Figure 4 c) or 6 c).

The surface finishing degree of the model pump shall be in accordance with Tables 5 and 7.

Requirements to be added for complementing the requirements in Tables 4 to 7 shall be as follows.

- a) In Figure 4, in the case of a mixed flow type with integrated semi-open vanes, the measuring points for the inlet tip diameter (D_1) and the side face height (H) shall be shifted by $(1 \text{ to } 2) \times T$ (T : vane thickness) from the vane tip in the meridian direction for the purpose of ensuring accuracy of measurement.
- b) When it is difficult, for structure or accuracy reasons, to measure the cross-sectional shape of the impeller (integrated type) by applying a connecting device between the vane inlet and outlet, the inlet side and the outlet side may be measured separately as far as the relative measurement points between the inlet and the outlet are recorded.
- c) The measurement of the vane inlet opening shall be performed on an impeller on which the continuous measurement of the vane cross-sectional shape according to **b)** is difficult.
- d) The measurement of the vane inlet opening shall be performed in an area free from interference of a shroud at the vane inlet and on the cross-sectional shape measuring section approximately $4T$ inside from the inlet edge, where T is the vane thickness. Depending on the circumstances, however, the measurement may be made at a position $T/2$ from the inlet edge (measurement at $4T$ is impracticable in many closed type impellers).
- e) For measurement of inlet opening of an impeller with relatively small specific speed and of a diffuser casing, if one end of the length measuring device touches the vane shroud or the diffuser casing wall making the measurement impracticable, the measurement need not be performed.
- f) The cross-sectional shape measuring points of a mixed flow integrated semi-open impeller, in general, are in the flow direction as shown in the left-hand figure of Figure 4 b), but the measurements may be performed in the radial direction as shown in the right-hand figure of Figure 4 b) when the boss-side measurements are difficult. The vane cross-sectional shape measurements may be substituted by measurement of the coordinates on the vane surface by means of a three-dimensional coordinate measuring device as shown in Figure 4 c). This applies to axial flow pumps also [see Figure 6 c)].

- g) The clearance in the wear ring portion of a closed impeller shall basically be similar to that of a prototype pump with respect to the number of annular clearance stages, length in each axial direction, mean clearance diameters, etc., but the annular clearance may be made larger as far as the operation test of the model pump is practicable. The effect of the annular clearance dimensions on the performance shall be calculated in accordance with Annex C.
- h) In a centrifugal pump equipped with both a diffuser and a volute casing, the surfaces of both flow passages shall be finished hydraulically smooth. If the pump has return channels, the surface roughness of those channels shall be $12.5\ \mu\text{m } Ra$ or less. The notation of the surface roughness shall be in accordance with **JIS B 0601**.
- i) For evaluation of surface roughness, it is practical to carry out comparison against roughness samples in addition to measurement using a measuring device. When a device is used, the measurements shall be made at one point at each of the inlet and outlet per vane.

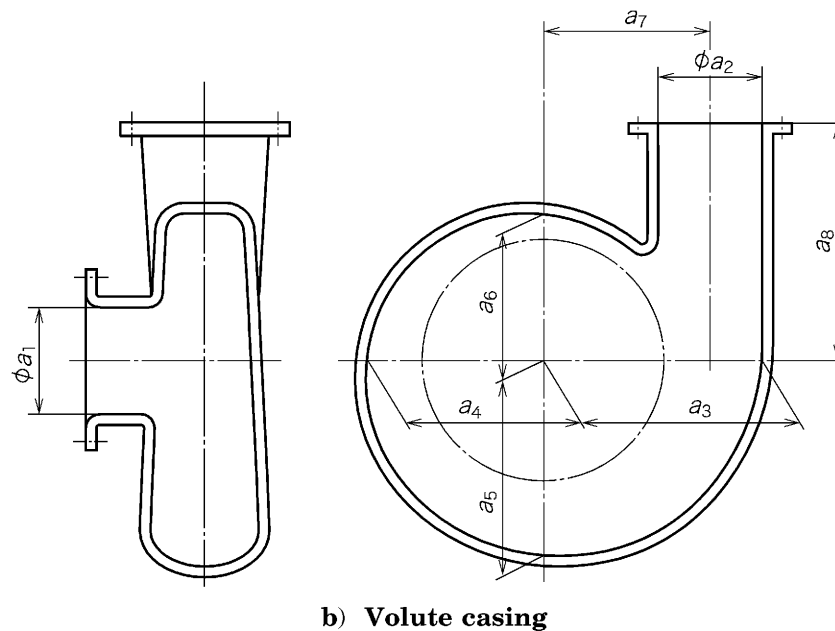
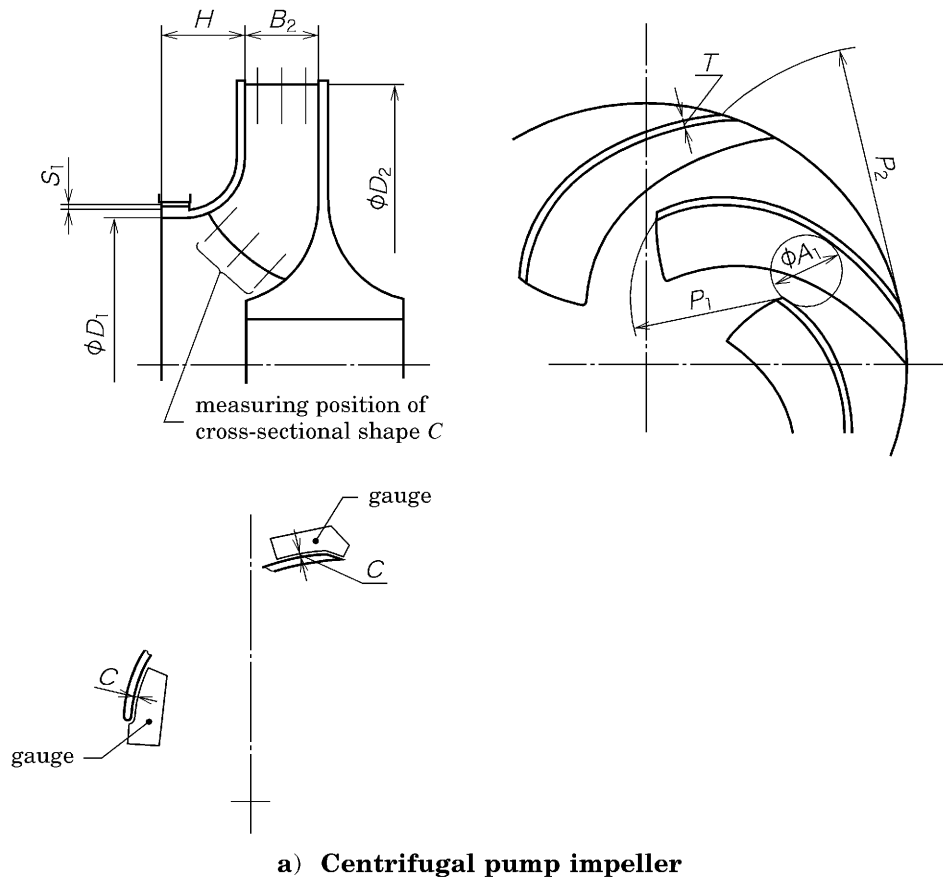
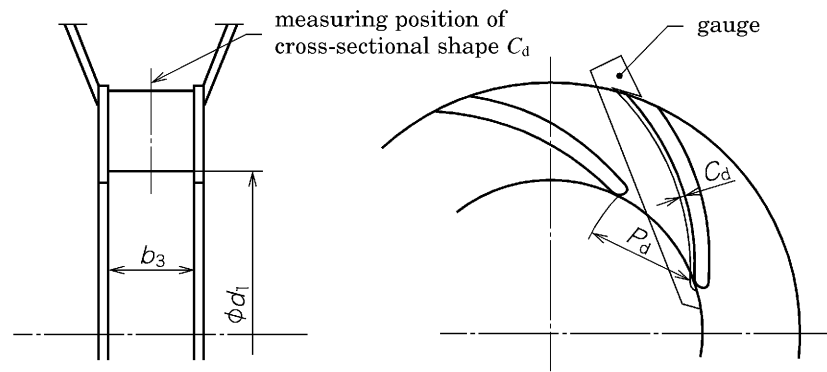
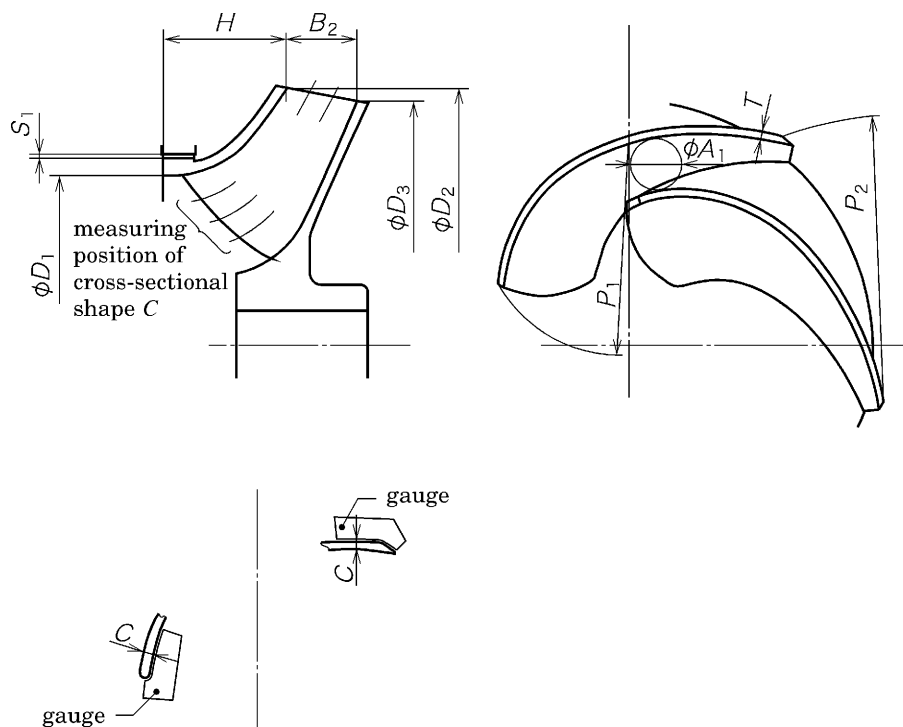


Figure 3 Illustration of dimension measuring positions of centrifugal pump



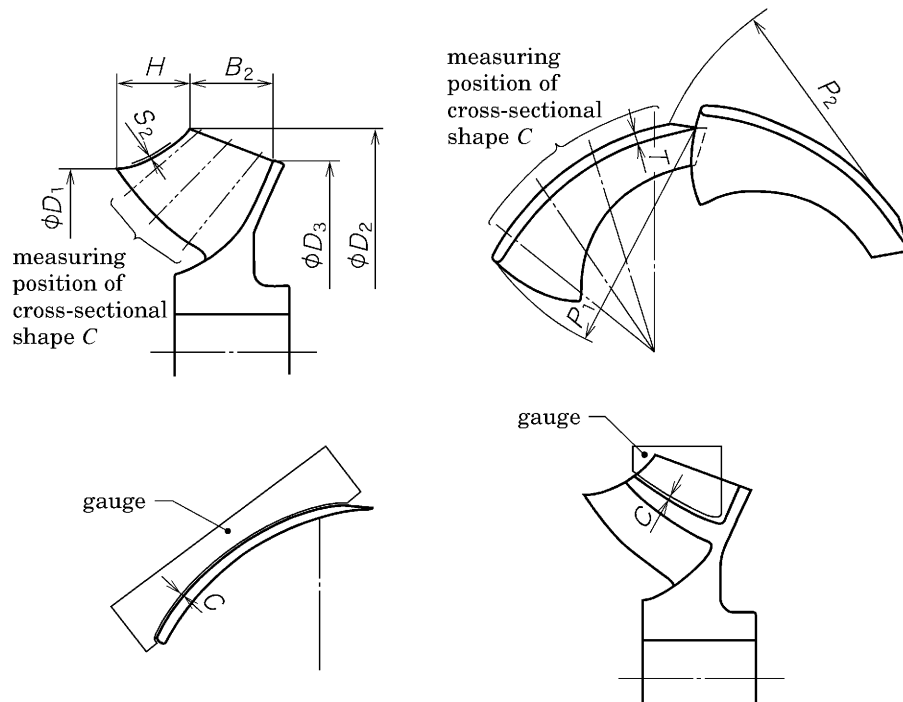
c) Diffuser vane

Figure 3 (concluded)

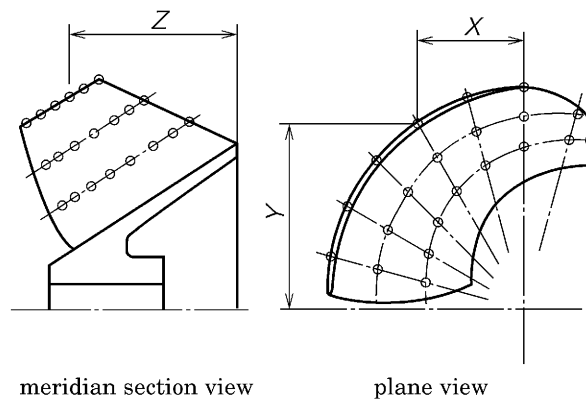


a) Mixed flow impeller (closed)

Figure 4 Illustration of dimension measuring positions of mixed flow pump impeller



b) Mixed flow impeller (semi-open)



c) Mixed flow impeller (semi-open), example of three-dimensional coordinate measurement of vane surface

Figure 4 (concluded)